



LHCb calorimeters and muon system lepton identification

F. Machefert

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BEAUTY 2003



Calorimeter and Muon System

Lepton Identification

Pittsburgh, October 14 – 18, 2003

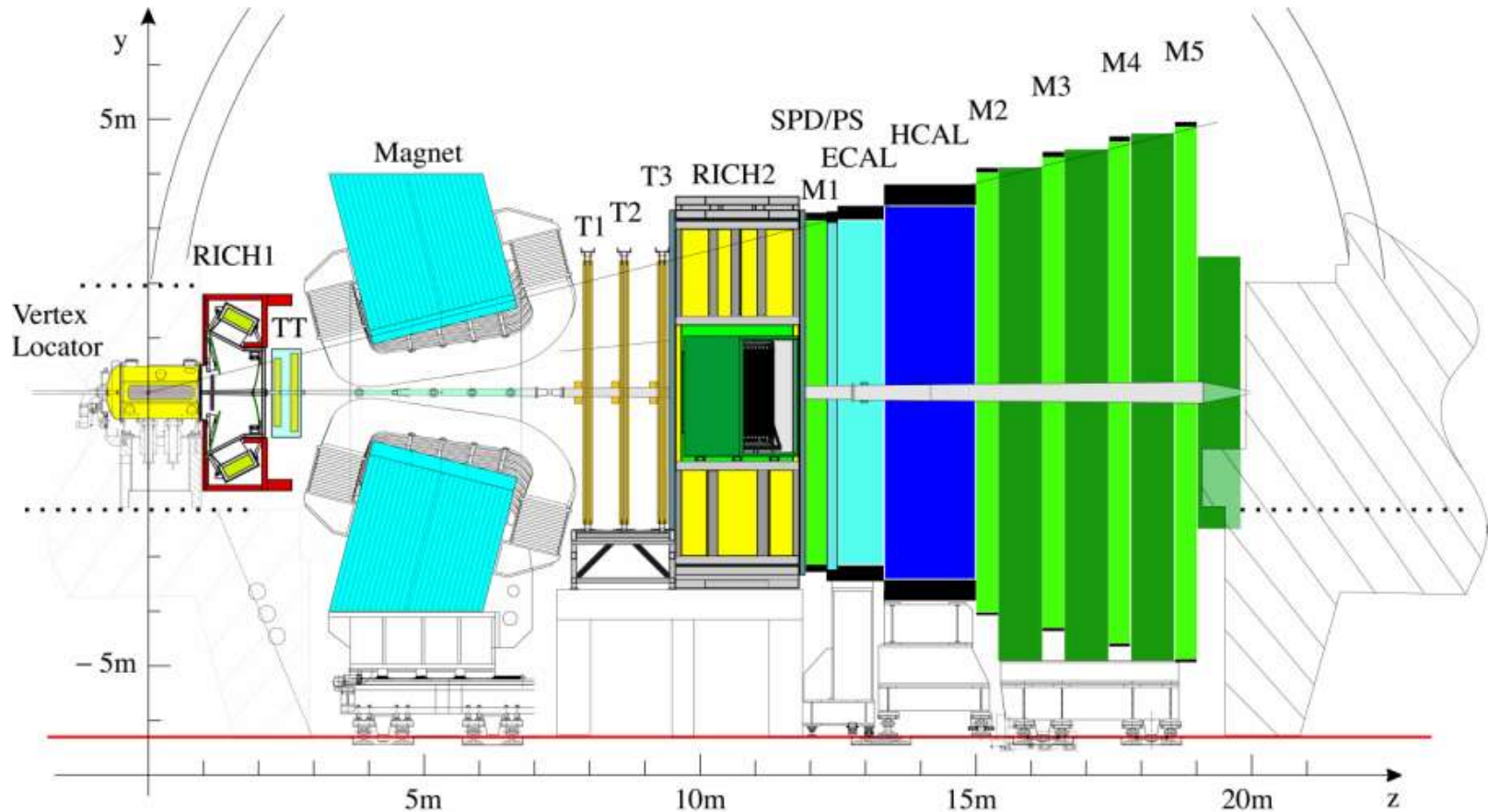
On Behalf of the LHCb Collaboration

Frédéric MACHEFERT



The LHCb experiment

- ❑ LHCb is dedicated to the Study of CP violation in the B meson system



- recent reoptimisation
 - ◆ VELO, RICH1, Tracking
 - ◆ Less material before Calorimeter ($\sim 70\%X_0$)

LHCb Calorimeters

Requirements :

- Identification of hadrons, electrons, γ , π^0
- Energy/ Position measurement
- L0 Trigger input : → see talk by O. Callot
 - ◆ High sensitivity
 - ◆ Fast response (40MHz)

Scintillator Pad Detector (SPD)

Preshower (PRS) → L0

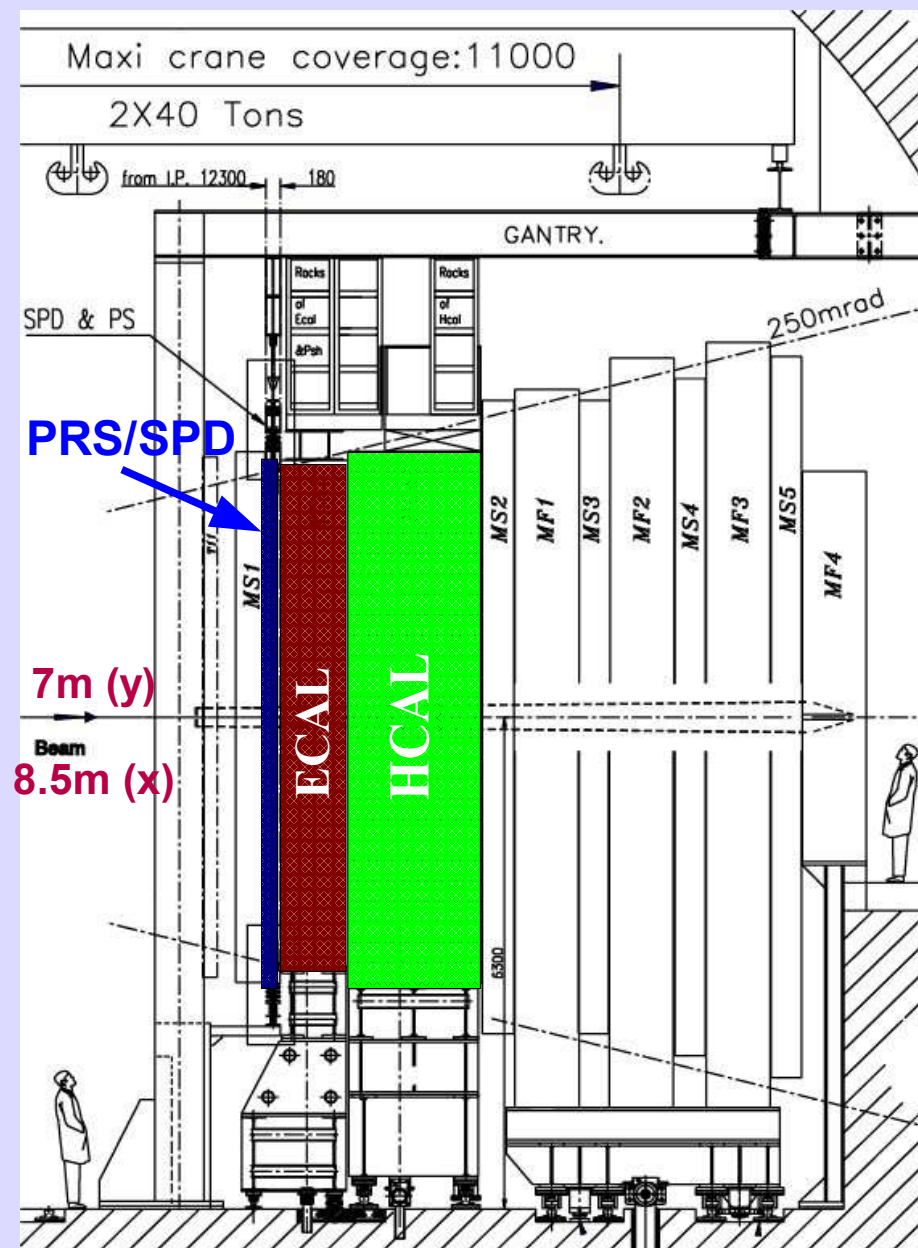
- γ / MIP separation (SPD)
- Electron, γ / π (PRS)
- Charged Multiplicity (SPD)

ECAL → L0

- Et of electron, γ
- π^0 offline reconstruction

HCAL → L0

- Et of hadrons
- Particle ID



SPD / PRS

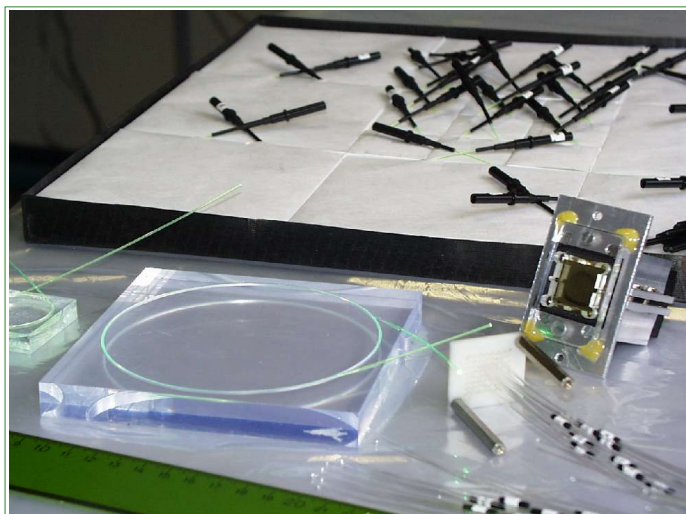


❑ Scintillating detector

- 2.5 X_0 lead converter sandwiched between two scintillator planes (pads)

❑ 3 zones : granularity depends on the occupancy

- Cell size : 40.4 / 60.6 / 121.2 mm
- ~ 6000 channels
 - ◆ Notice : 3 same zones for ECAL (HCAL : 2 zones)
- Projective Calorimeters



❑ L0 :

- ECAL finds local E_t maxima
- SPD/PRS determines electromagnetic nature of energy deposit

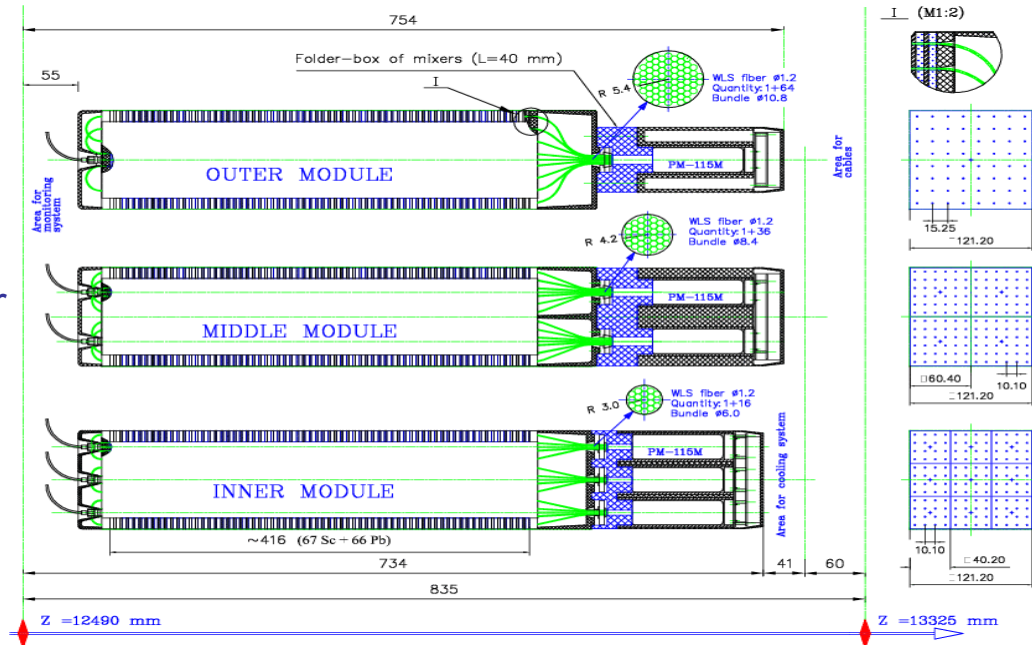
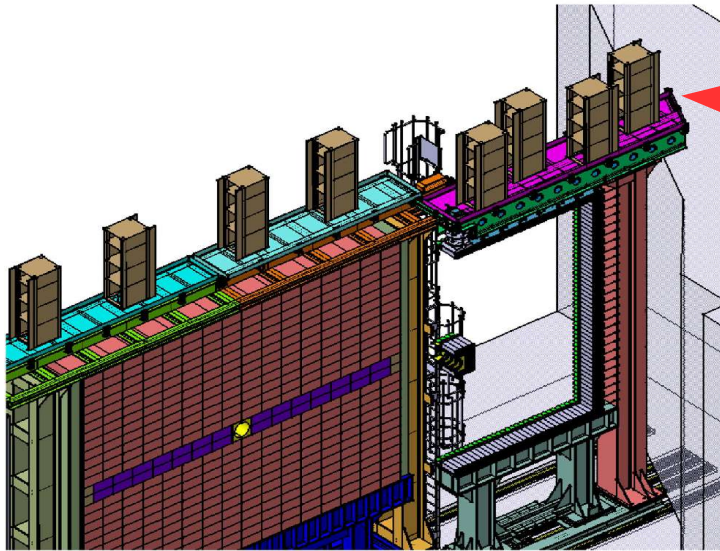
❑ Signal read with MAPMT

❑ Dynamic range : 0 – 100 Mips

- 10 bits (PRS) + 1 bit (SPD)

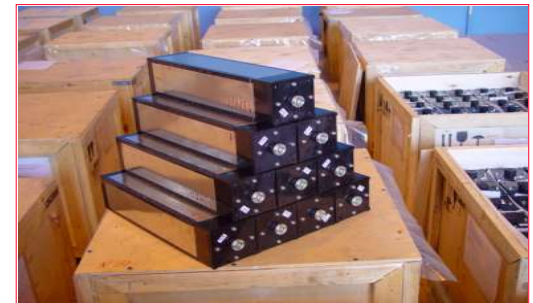
Shashlik technology

- Radiation resistance
- Fast response
- 66 layers of 2mm Pb / 4mm scintillator
 - ◆ $25 X_0$, $1.1 \lambda_I$
- WLS fibres transport signal to PMT



ECAL front-end/L0 electronics

- Installed on top of sub-detectors (200rad/y)
- Low noise front-end integrator
- Et range : 0 - 10GeV (12 bits)

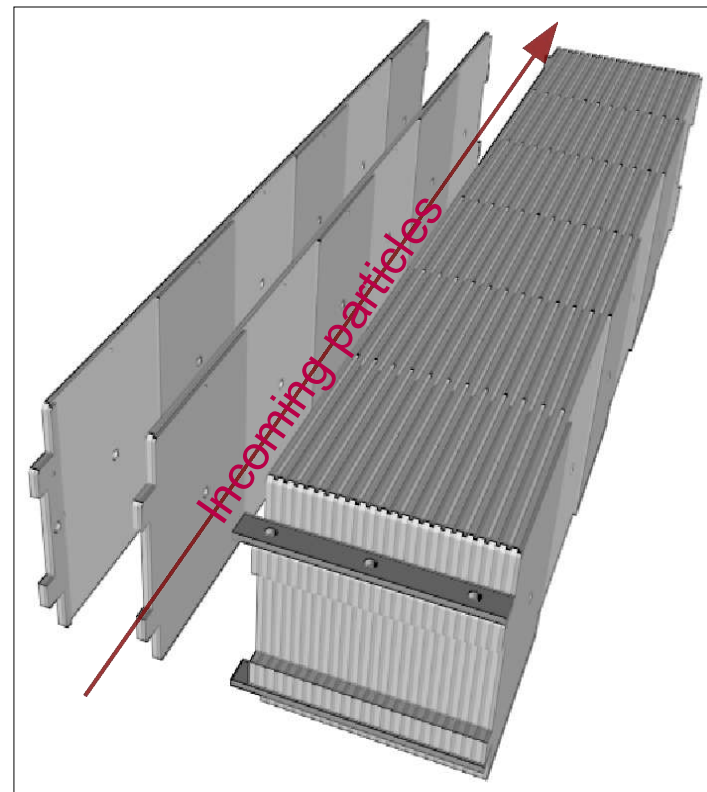


■ 90% of the modules delivered to CERN

HCAL

Longitudinal tiles

- Iron and scintillator tiles
 - ◆ 6mm master, 4mm spacer / 3mm scintillator
 - ◆ $5.6 \lambda_I$
- 2 zones (1468 channels)
- Signal propagates with WLS fibres to PMT



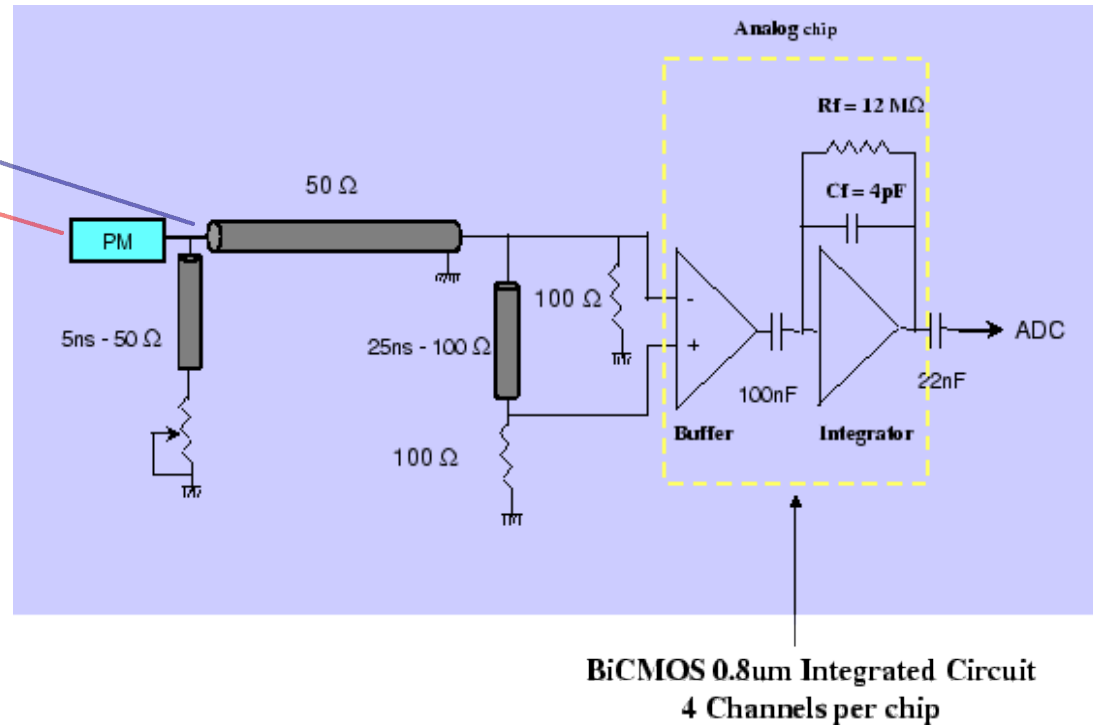
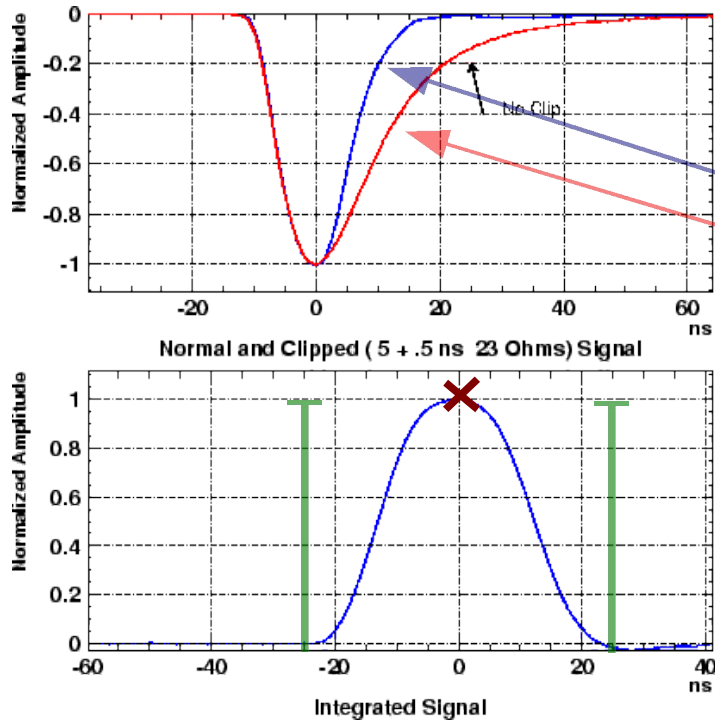
- Same front-end electronics as ECAL

- 30% of the modules already delivered

ECAL-HCAL Electronics

Scintillator + WLS fibre : fast system

Try to measure every bunch crossing : no pileup effect (residue after 25 ns : < 1%)



Digital electronics based on Actel anti-fuse technology

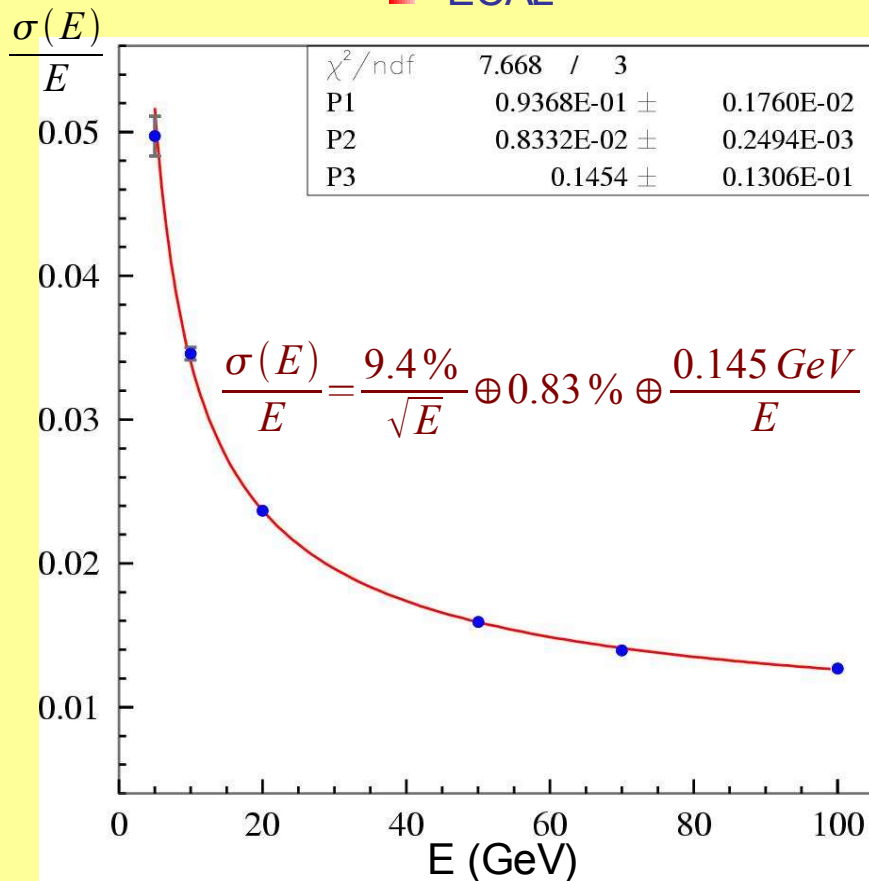
- FPGA configuration insensitive to Single Event Effects
- Protection by Parity code and Triple Voting

All components have been tested in proton and ion beams

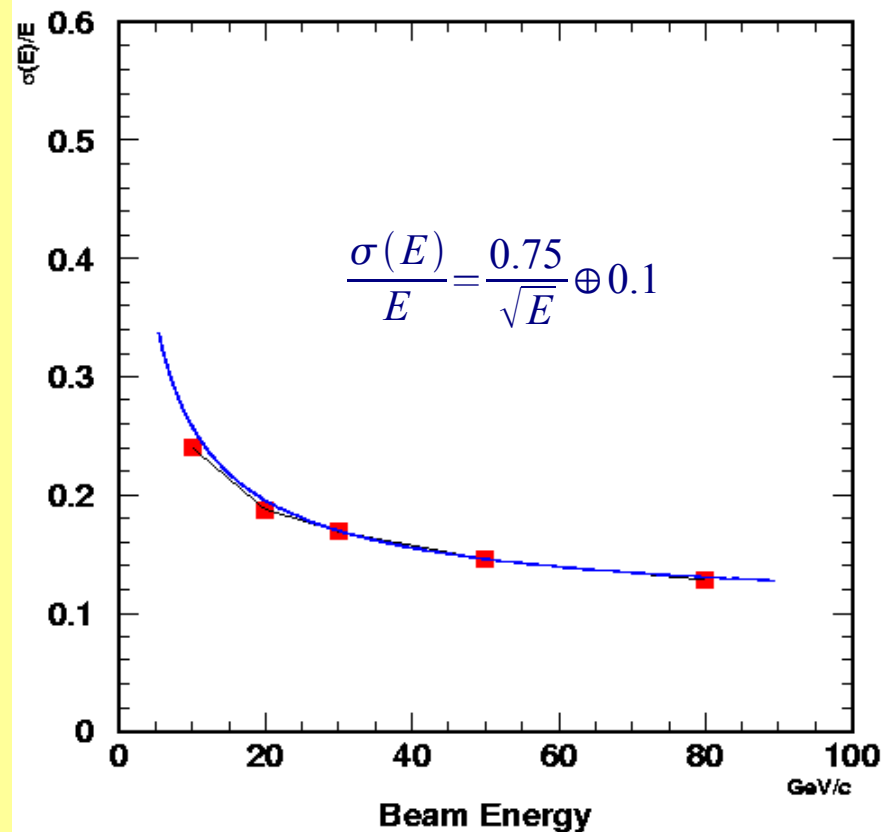
Energy Resolution

Energy Resolution of series modules (test beam measurements)

■ ECAL



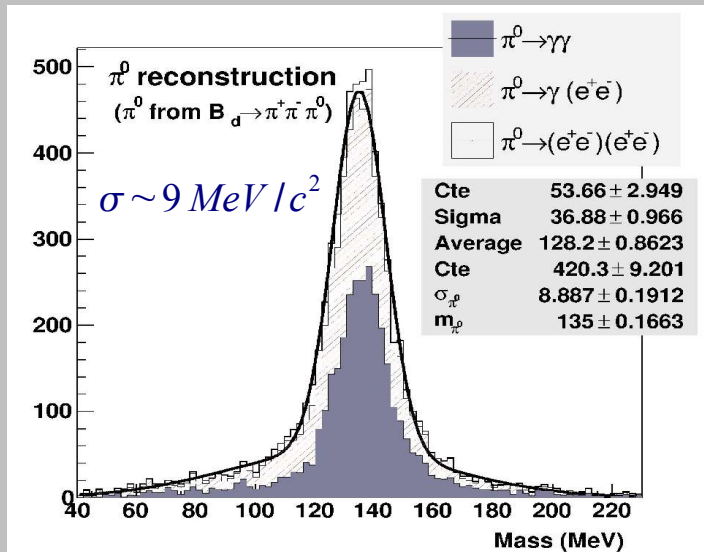
■ HCAL



Calorimeter Performances : π^0 reconstruction

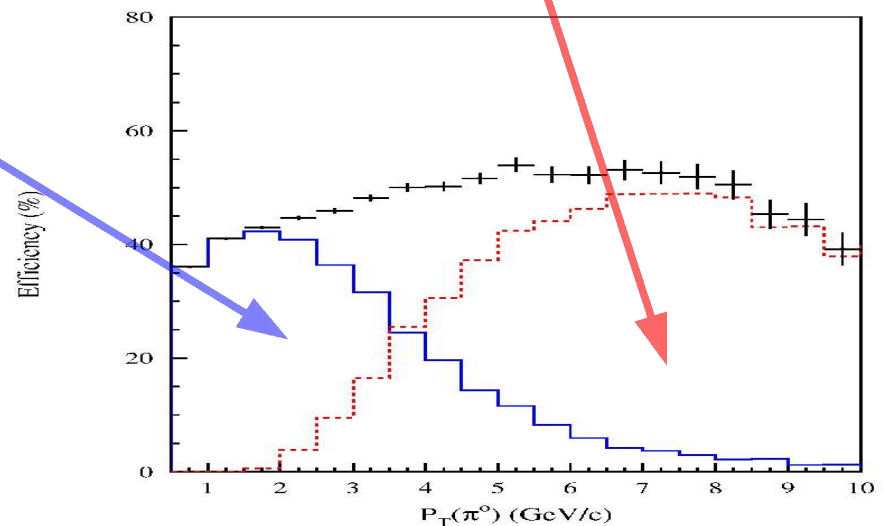
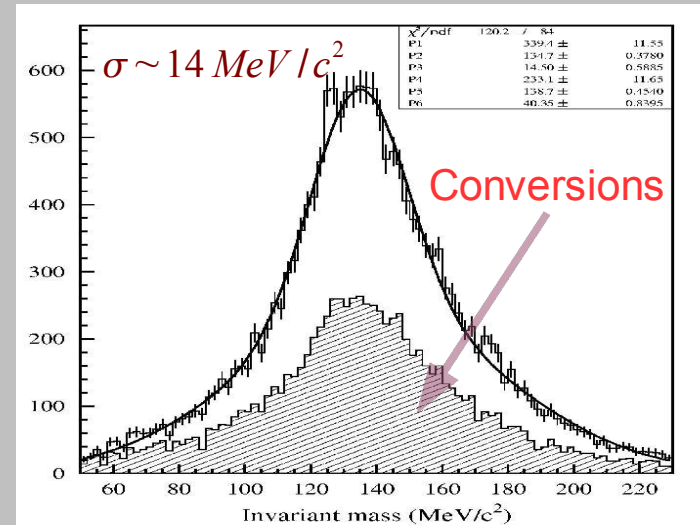
■ π^0 reconstruction efficiency

■ Resolved π^0 (2 clusters)



π^0 efficiency inside detector acceptance $\sim 50\%$

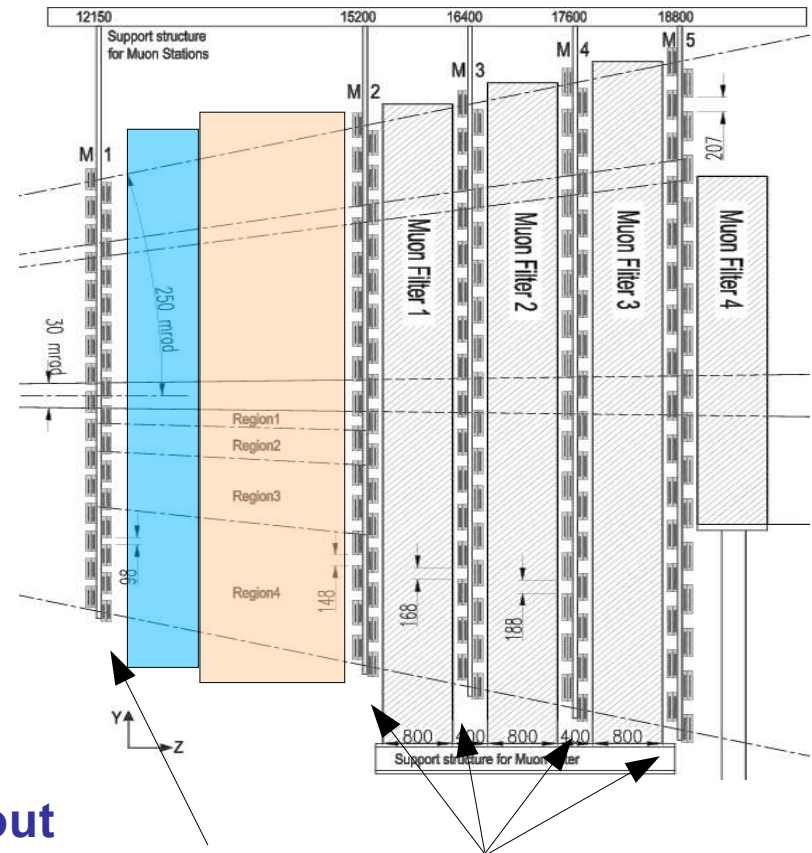
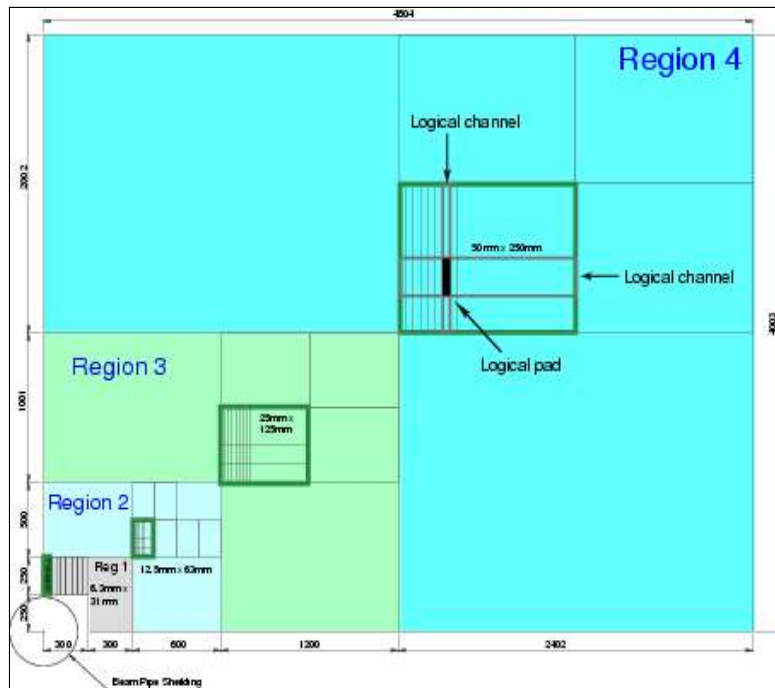
■ Merged π^0 (1 cluster)



Muon System

Requirements

- Muon triggering (L0)
 - ◆ Fast measurement / Bunch crossing id.
 - ◆ High efficiency (down to $p=5\text{GeV}/c$)
 - ◆ Pt resolution $\sim 20\%$
- Muon offline identification
 - ◆ Tagging + reconstruction
 - $\epsilon > 90\%$, mid-id $< 1.5\%$



Layout

- 5 stations : 1x(2 layers)+ 4x(4 layers)
- Projective geometry

Granularity : Stations divided in 4 regions

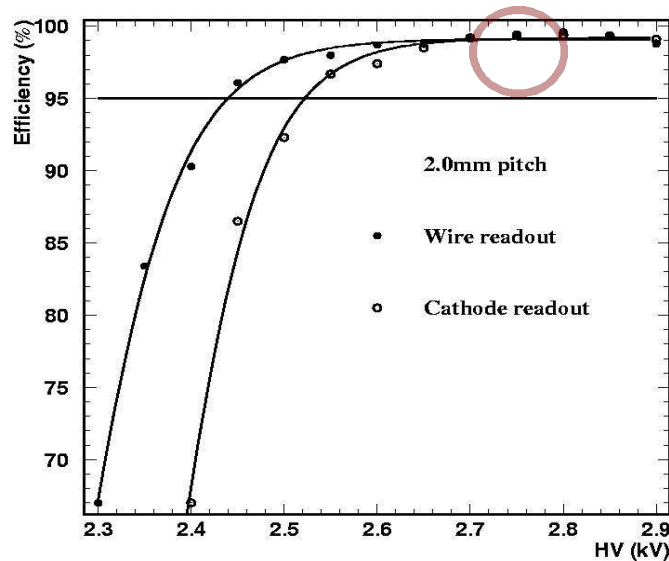
- X-dim : L0 pt resolution
- Y-dim : background rejection
- Logical pads from logical channels

435m² – 1380 chambers – 26k channels

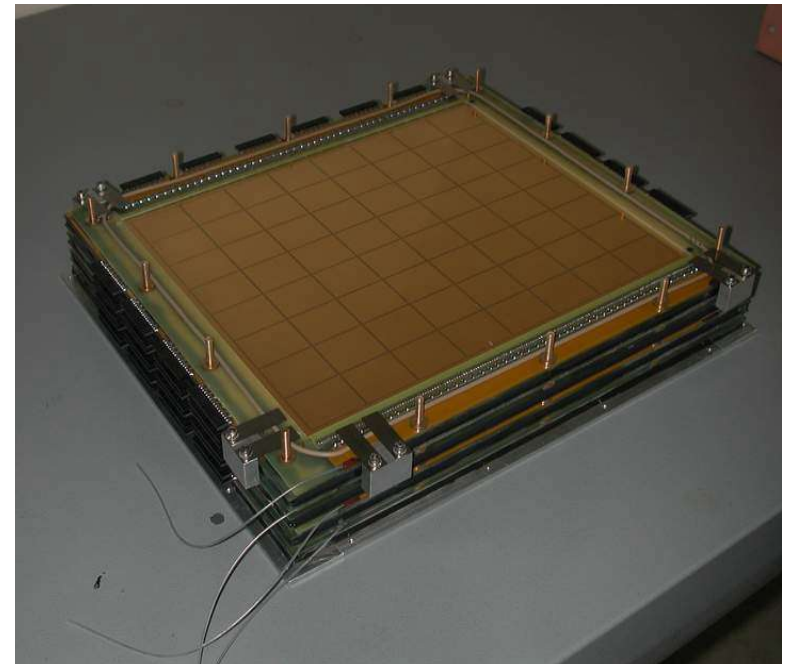
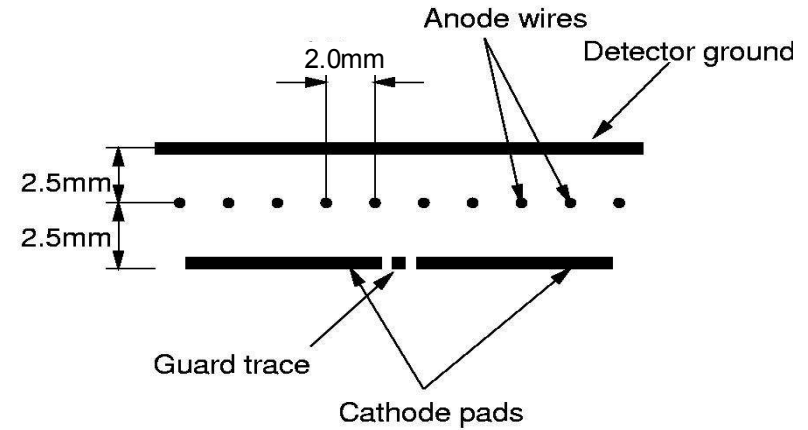
MWPC

□ MWPC

- Wire/cathode reading
- 2mm wire pitch $\epsilon=99\%$ (20ns-2 gaps)
- Time resolution : 4ns
-



- M1 radiation length : $0.15X_0$
(Nomex Honeycomb)



Pre-series MWPC

□ Central Part M1 (0.6m²) : Triple-Gem ?

Muon system electronics

□ Muon electronics Architecture

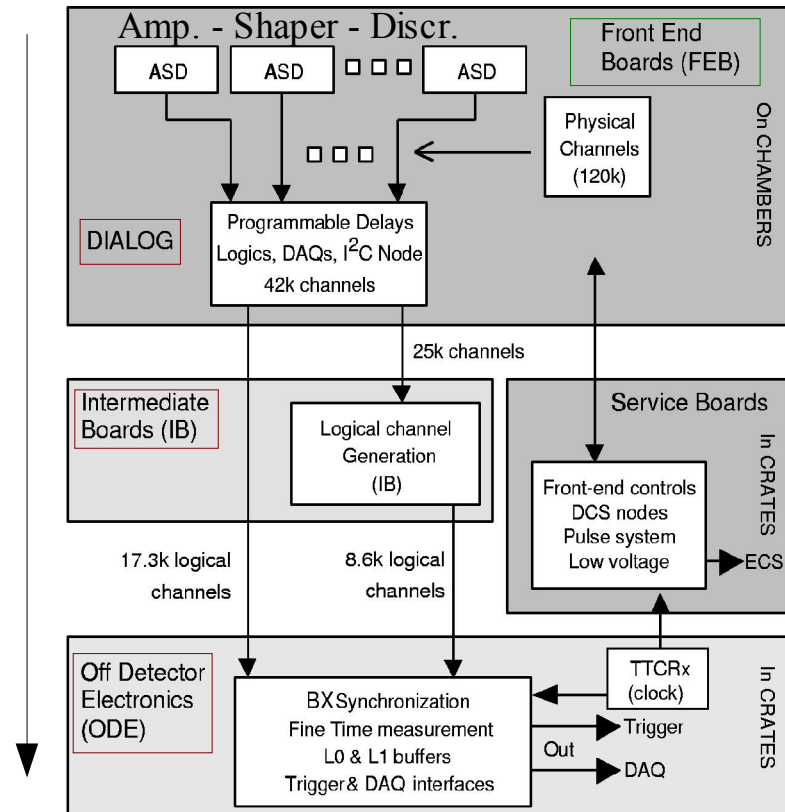
■ Physical Channels : 120k

■ Logical pads : 26k

◆ Made from

- strip crossing
- physical pads

■ L0 / L1 / DAQ



□ MWPC pre-series production started

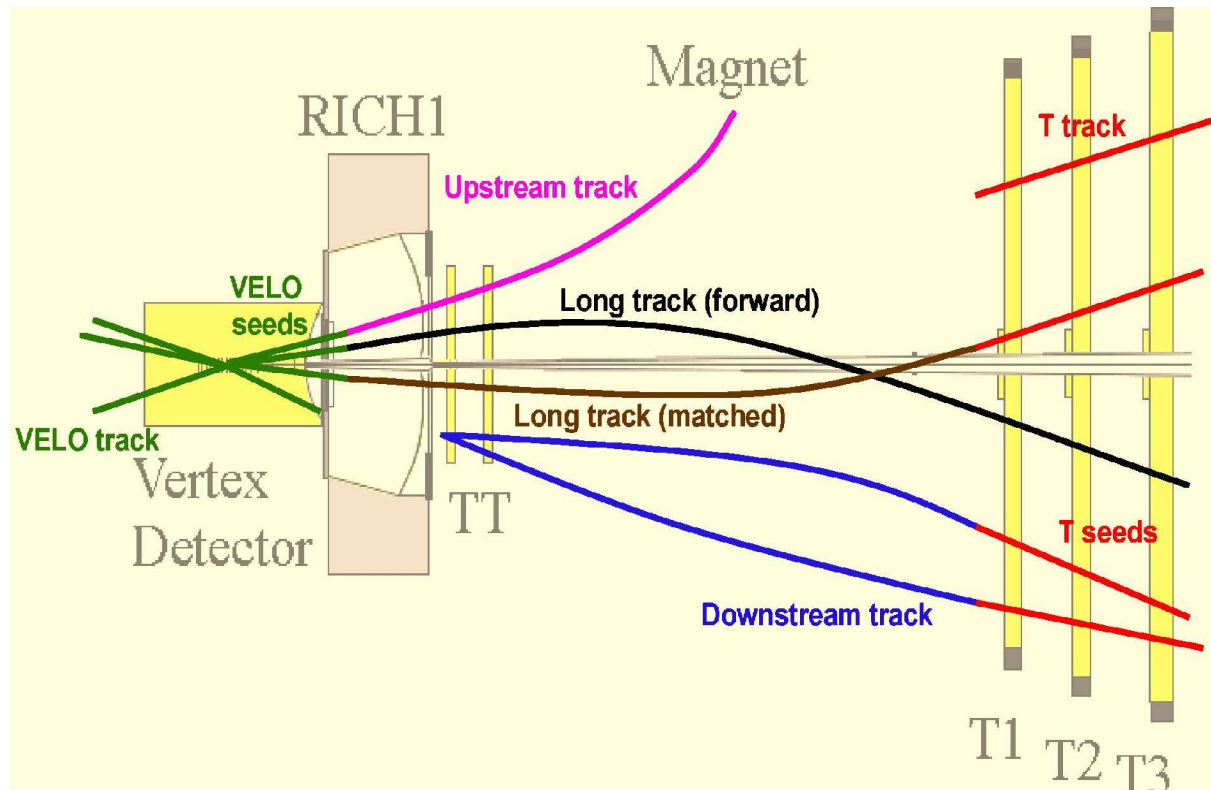
□ Several sites are ready (tooling and clean room) for production

□ Electronic Architecture has been reviewed and approved

■ Final version of most chips has been received

Lepton identification : Tracking

Tracking performance

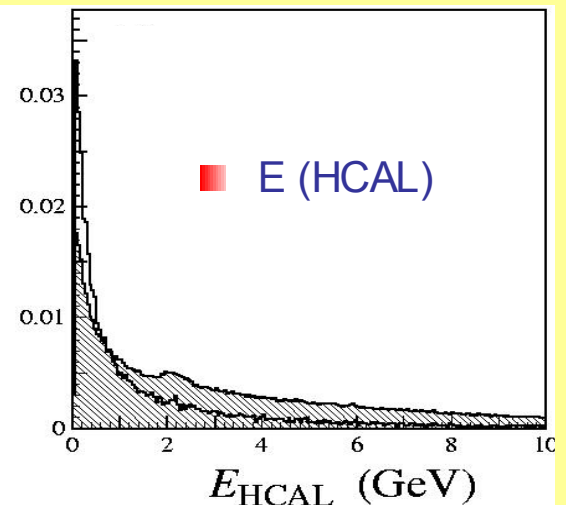
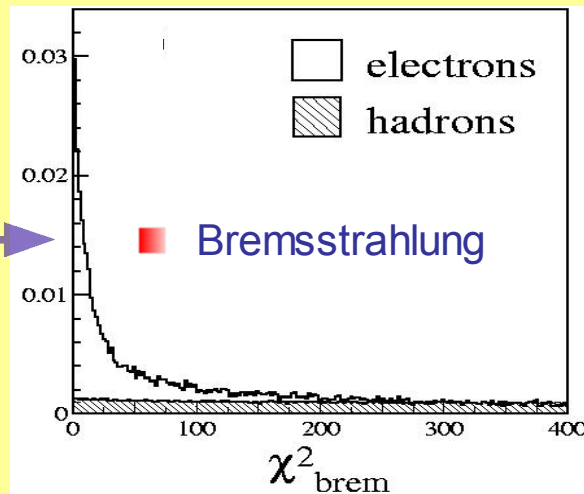
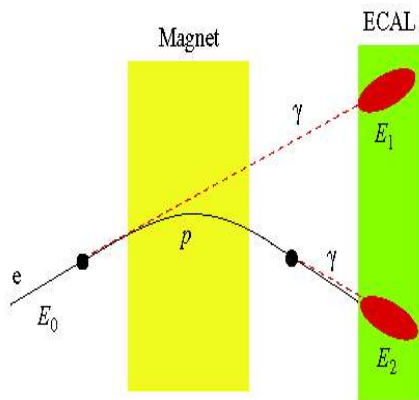
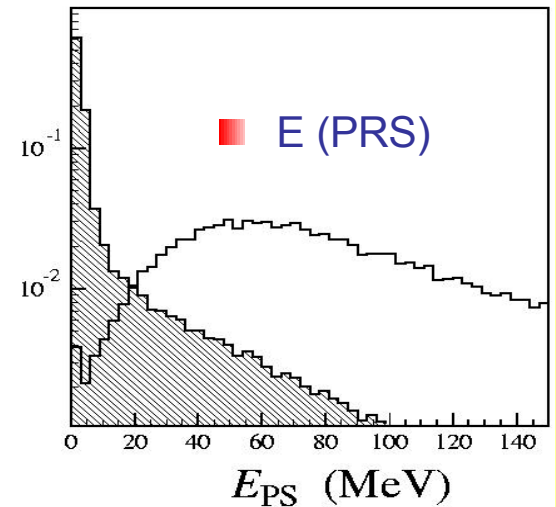
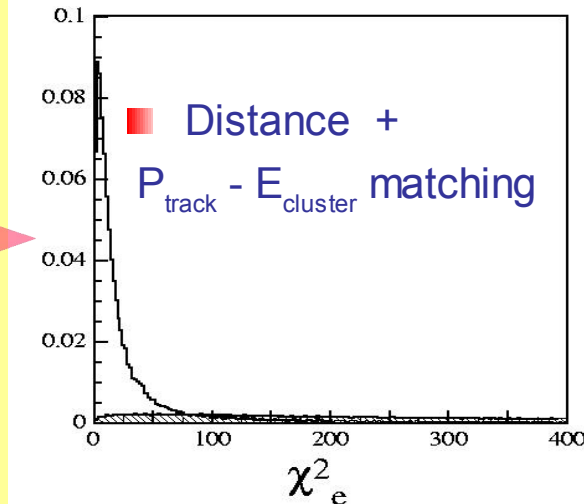
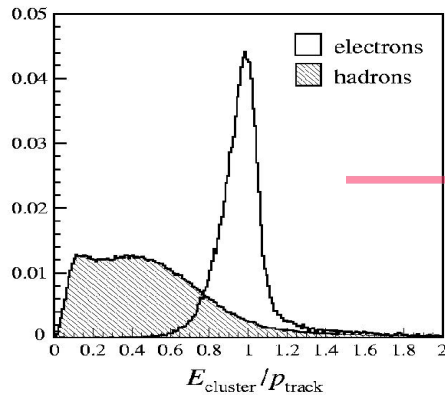


□ $\epsilon = 94\%$ - $P > 10\text{GeV}$

□ $R_{\text{Ghost}} \sim 3\%$ - $P_{\text{cut}} = 0.3\text{GeV}$

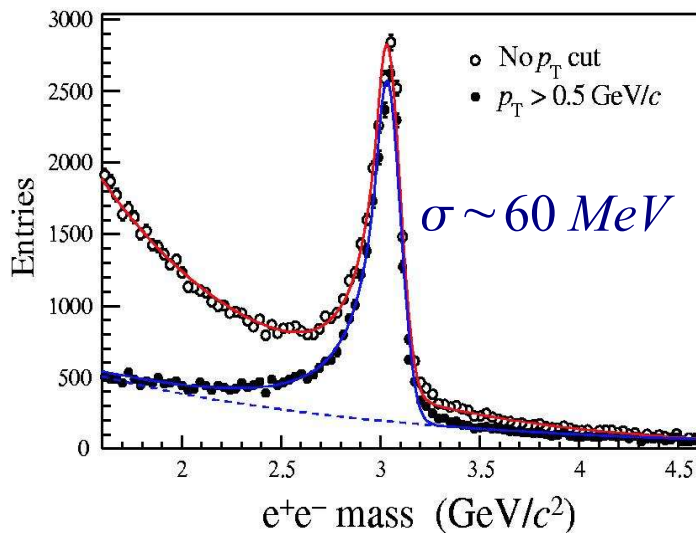
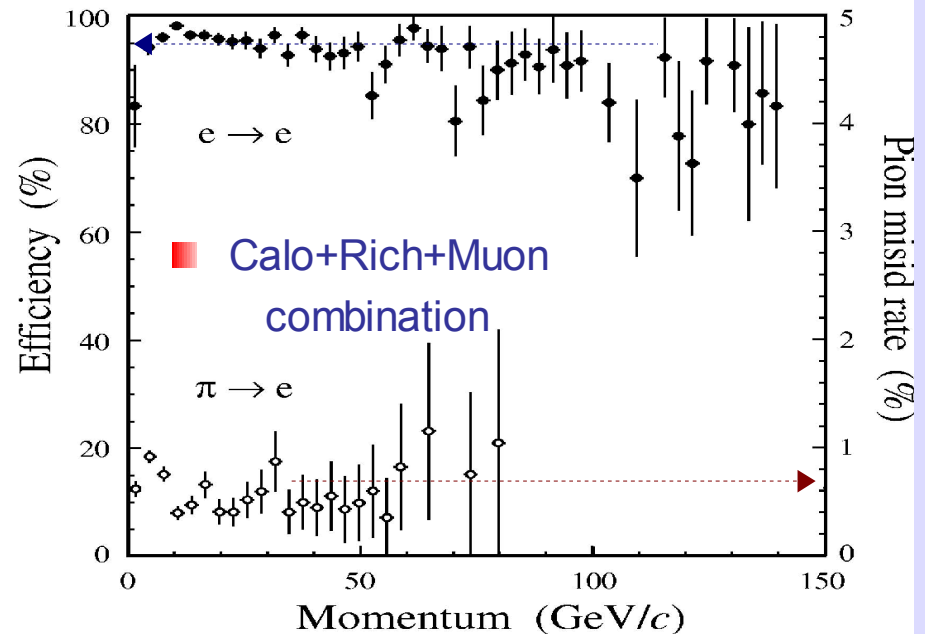
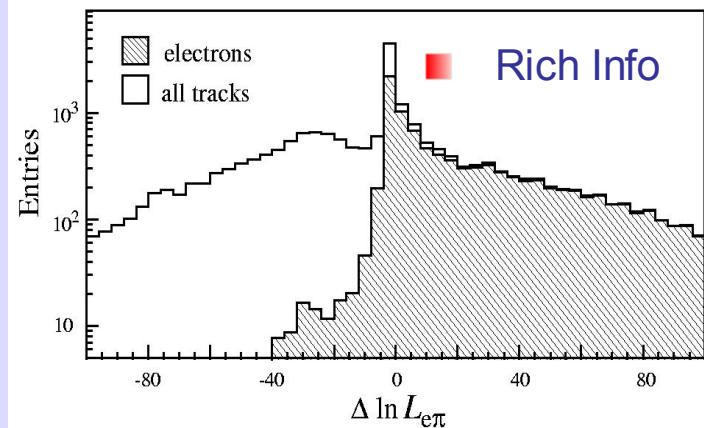
Electron Identification (I)

- Require impact of a track near a calorimeter cluster
- Build 4 parameters :



Electron Identification (II) : combined analysis

Combine Calo + Rich + Muon

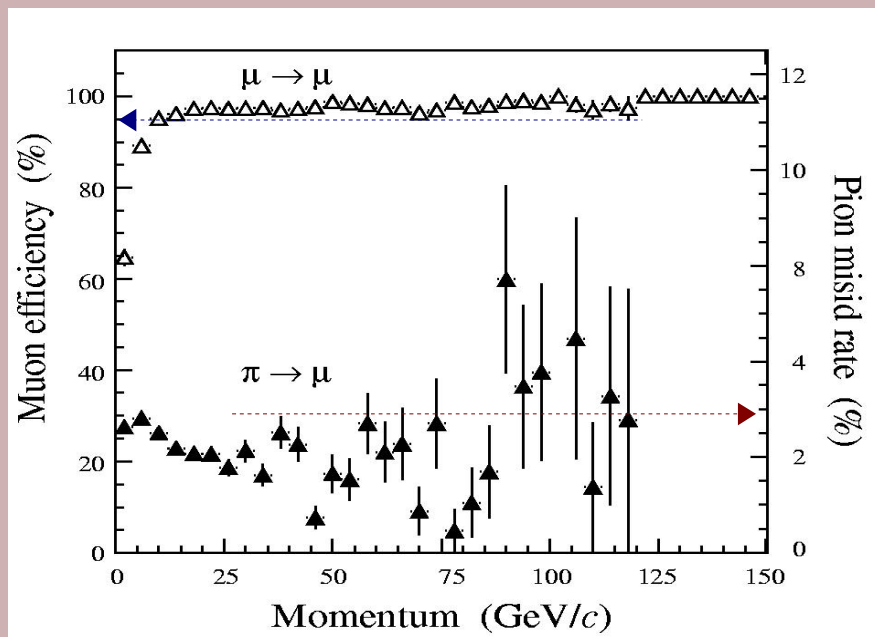


$J/\Psi \rightarrow e^+ e^-$ ($B_s^0 \rightarrow J/\Psi \Phi$)
 $\varepsilon(e)=95\% - \varepsilon(\pi \rightarrow e)=0.7\%$

Muon Identification (I)

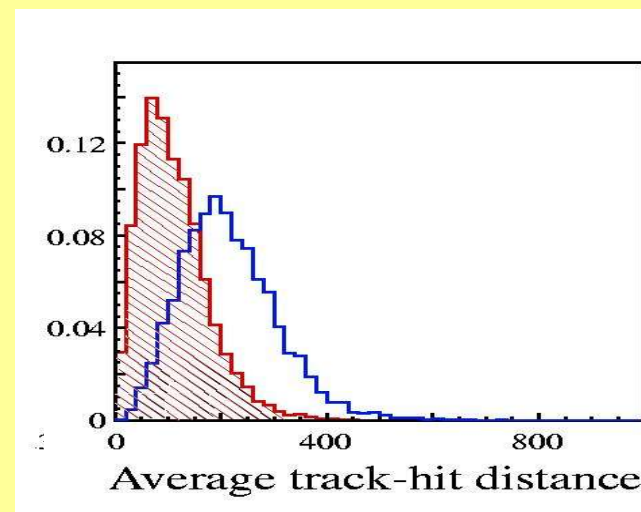
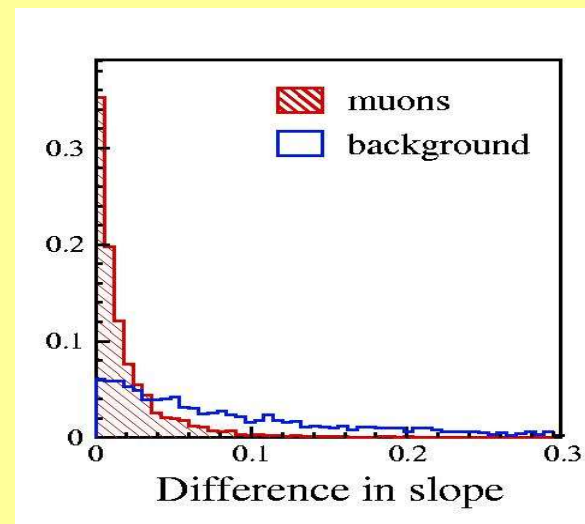
- Definition of Fields of Interest around track extrapolation
- Require hits in # stations in FOI

Momentum (GeV)	Muon Stations
$3 < P < 6$	M2 + M3
$6 < P < 10$	M2 + M3 + (M4 or M5)
$P > 10$	M2 + M3 + M4 + M5



$$\epsilon(\mu) = 94.3\% - \epsilon(\pi \rightarrow \mu) = 2.9\%$$

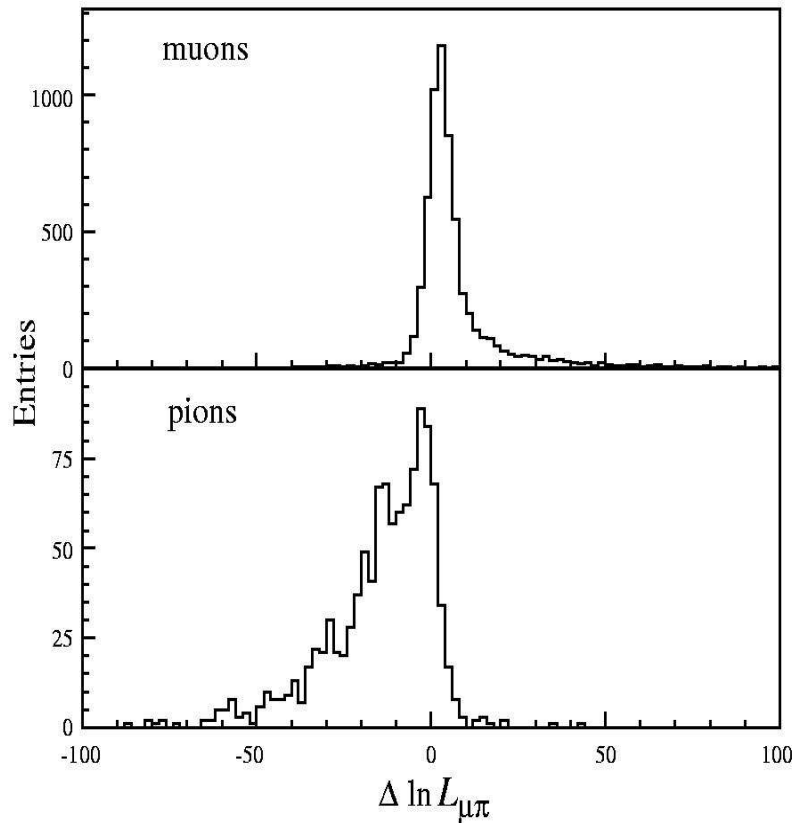
- Estimator to further reject pions



Muon Identification (II)

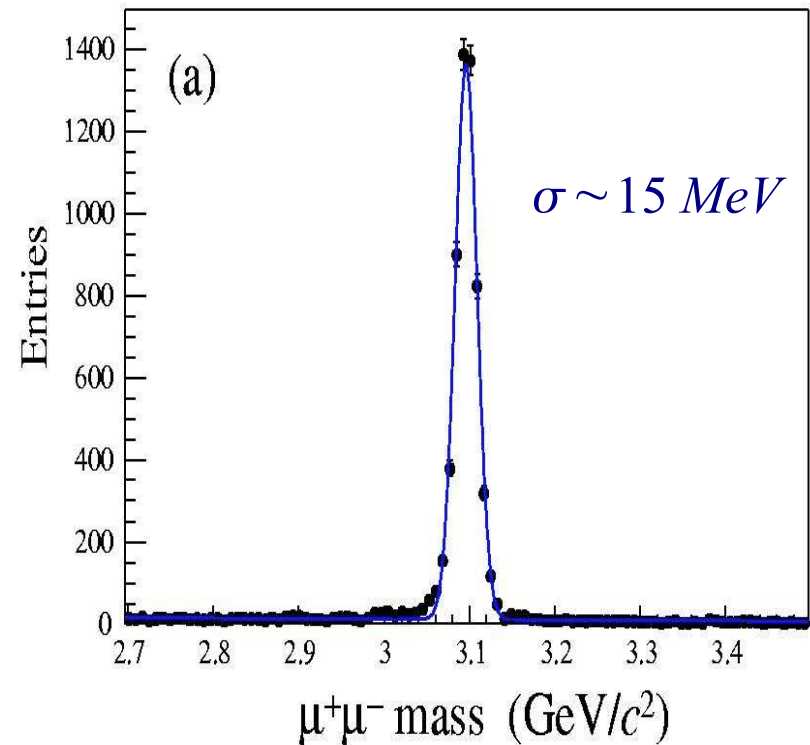
Combine Muon+Rich+Calo

Further improves selection wrt FOI only



$J/\Psi \rightarrow \mu^+ \mu^-$ ($B_s^0 \rightarrow J/\Psi \Phi$)

$\epsilon(\mu)=93\% - \epsilon(\pi \rightarrow \mu)=1\%$



Conclusion

Calorimeter

- Complementary systems
 - ◆ SPD / PRS / ECAL / HCAL
- L0
- Fast / sensitive / efficient / robust

Muon system

- Simple (all MWPC) / robust
- L0
- Logical channel : no geometrical ambiguity

Lepton Identification ($B_s^0 \rightarrow J/\Psi \Phi$)

- Electrons : $\varepsilon(e) = 95\%$ - $\varepsilon(\pi \rightarrow e) = 0.7\%$
- Muons : $\varepsilon(\mu) = 93\%$ - $\varepsilon(\pi \rightarrow \mu) = 1\%$

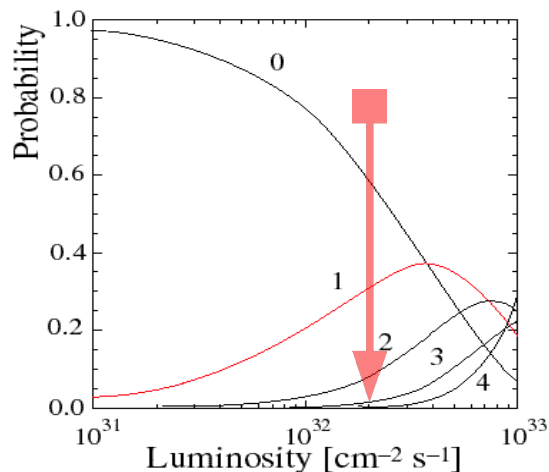
LHCb will be ready for data taking in 2007 at LHC start-up

- Detector production is on schedule
- Detector installation starts at the end of next year (magnet installation ongoing)

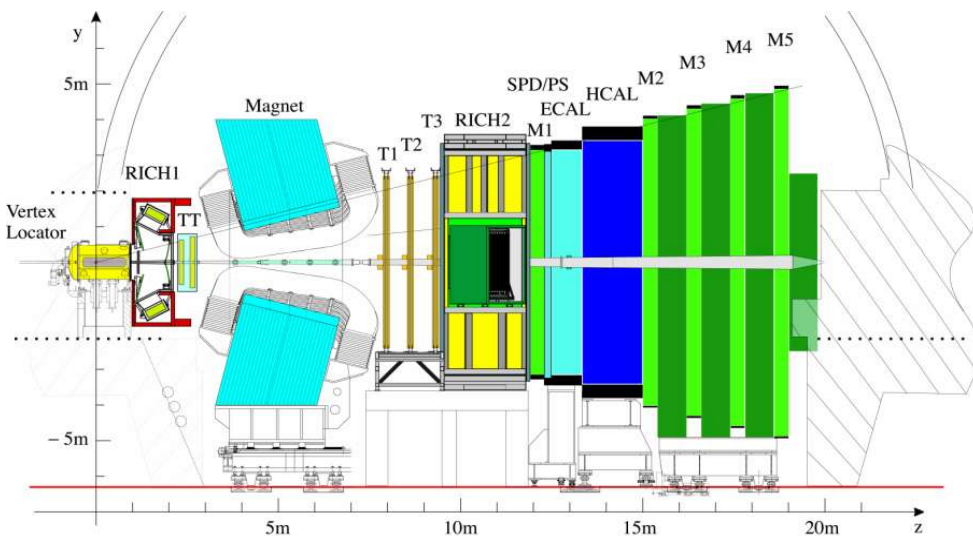
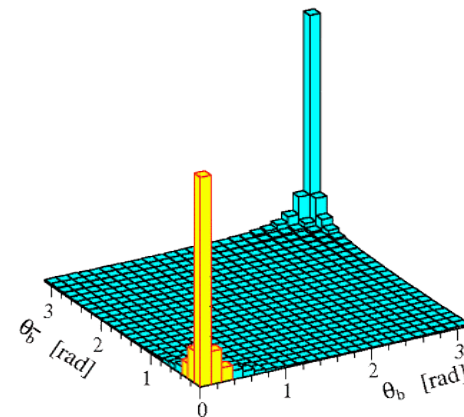
Backup Slides

The LHCb experiment

□ LHCb is dedicated to the Study of CP violation in the B meson system



- pp collisions at $\sqrt{s} = 14 \text{ TeV}$
- forward $b\bar{b}$ production correlated
- $\sigma_{\text{total}} \sim 100 \text{ mb} \rightarrow \text{Int. Rate} : 2 \times 10^7 \text{ Hz}$
 - ◆ $\sigma_{b\bar{b}} \sim 500 \text{ } \mu\text{b}, \sigma_{\text{inel}} \sim 80 \text{ mb}$
 - ◆ $S/B \sim 1\%$
- $10^{12} \text{ } b\bar{b} \text{ pairs per year}$



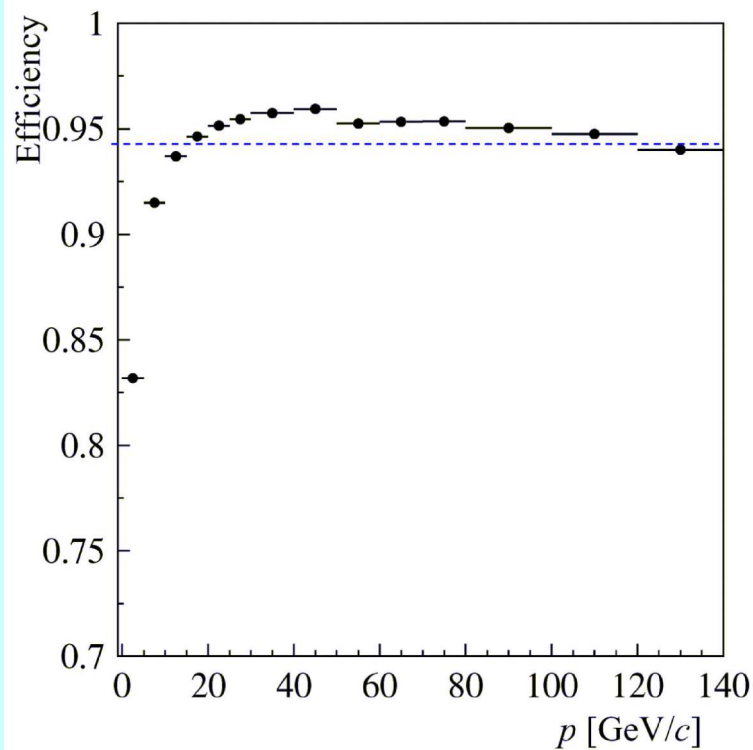
□ LHCb

- Mostly single interactions (PileUp Veto)
 - ◆ $L_{\text{nom.}} = 2 \times 10^{32} \text{ cm}^{-2} \cdot \text{s}^{-1}$
- $12 \text{ mrad} < \theta < 300 \text{ mrad}$
- efficient trigger ($L0 \sim 1 \text{ MHz}, L1 \sim 40 \text{ kHz}$)
- recent Re-optimisation
 - ◆ VELO, RICH1, Tracking
 - ◆ Less material before Calorimeter

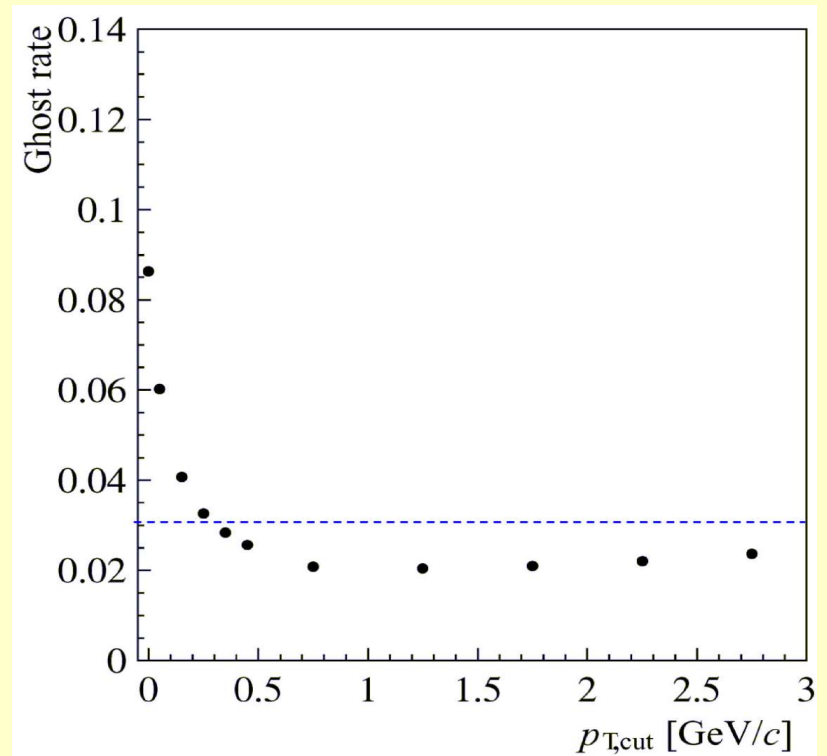
Lepton identification : Tracking

Tracking performance

■ Efficiency



■ Ghost Rate



■ $\epsilon = 94\%$ - $P > 10 \text{ GeV}$

■ $R_{\text{Ghost}} \sim 3\%$ - $P_{\text{cut}} = 0.3 \text{ GeV}$

Lepton Identification Robustness

Electrons (Calo effects)

- Coherent / incoherent noise increase
 - ◆ +50 up to +100%
- Dead channels
 - ◆ 1%(PRS/SPD) – 0.2% (ECAL/HCAL)
- Channel gain error
 - ◆ +50%
- No re-tuning (nominal reference histo)

$\epsilon(e)$ loss of 2.5%

$\epsilon(\pi \rightarrow e) = 0.7\% \rightarrow 1\%$

Electrons (ex. of track multi. Effect)

- Increase track multiplicity by x2

$\epsilon(e)$ unaffected

$\epsilon(\pi \rightarrow e) = 0.7\% \rightarrow 1\%$

Muons (Muon system effects)

- Increase low energy background by x5
- No re-tuning

$\epsilon(\mu) = 94\%$ unaffected

$\epsilon(\pi \rightarrow \mu) = 2.9\% \rightarrow 11.7\%$

- After algorithm re-tuning

$\epsilon(\mu)$ loss of 7%

$\epsilon(\pi \rightarrow \mu)$ back to 2.9 %

